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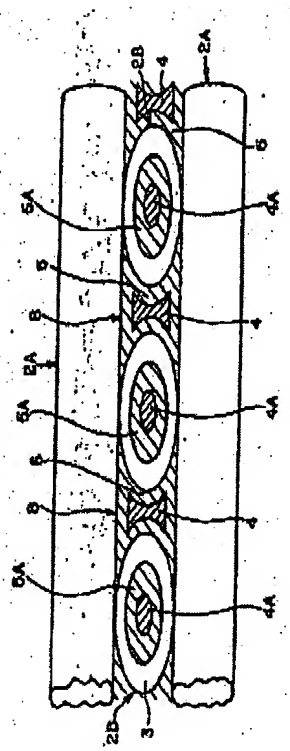



(54) [Invention Title] Highly Oxidation Resistant Silicon Impregnated Composite Material, as well as its production method.

(57) [Summary]

[Task] Delivering a new Highly Oxidation Resistant Silicon Impregnated Composite Material with an increased resistance to oxidation under high temperatures.

[Solution Method] This is achieved through making Highly Oxidation Resistant Silicon Impregnated Composite Material from 1): a Silicon-Silicon Carbonaceous Material Phase in which metallic silicon, silicon carbide and boron carbide have been dissolved and impregnated in the inside of the opened gas pocket of the fired substance fired and formed with yarn sequences and yarn sequence related material using binders that do not include any boron carbide, silicon carbide, or metallic silicon, and from 2): a skeletal frame made primarily from carbon fiber, and from
3): Silicon-Silicon Carbonaceous Material that form around the skeletal frame, and from
4): Matrices formed with Boron Carbide. In addition, for this invention to be achieved

the previously stated matrices and the previously stated skeletal frame must be integrated into one unit and the gas pocket rate must be 10% or lower.

[Scope Of Claim]
[Claim 1] It is a Highly Oxidation Resistant Silicon Impregnated Composite Material made up of silicon carbide, metallic silicon, carbon essentially made from carbon fiber, and boron carbide that can be included upon request. In addition, this Highly Oxidation Resistant Silicon Impregnated Composite Material has a structure made from the matrices that form in and around the skeletal frame,
and at least 50% of the silicon carbide are Beta Models.
In addition, the frame is made from carbon fiber bundles, Silicon-Silicon Carbonaceous Material comprised from metallic silicon and silicon carbide formed inside or around the carbon fiber bundle, and boron carbide that can be included upon request.
In addition, the matrices are made from Silicon-Silicon Carbonaceous Material comprised of silicon carbide and metallic carbide, and boron carbide that can be included upon request.

Furthermore, the previously stated matrices and the previously stated skeletal frames are integrated together into one unit, and, the previously stated Composite Material is a Highly Oxidation Resistant Silicon Impregnated Composite Material that is characterized as having a gas pocket rate of less than 10%.

[Claim 2] The Highly Oxidation Resistant Silicon Impregnated Composite Materials stated in Claim 1 that has a characteristic of the previously stated matrices forming along the surface of the skeletal frame.

[Claim 3] A Highly Oxidation Resistant Silicon Impregnated Composite Material stated in Claim 1 and Claim 2 characterized by a silicon content ratio of silicon inside the Silicon-Silicon Carbonaceous Material that make the previously stated matrices, and/or inside the Silicon-Silicon Carbonaceous Material that form inside and/or around the Silicon carbon bundle, that increases the further away it is from the surface of the previously stated skeletal frame.

[Claim 4] The previously stated skeletal frame is one of the Highly Oxidation Resistant Silicon Impregnated Composite Materials stated in Claim 1-3 that has the following characteristics.
The skeletal frame is manufactured with compact objects made from Yarn aggregations that were formed by laminating the necessary amount of yarn sequences made by arranging at least a multiple number of carbon fiber yarns and carbon components other than carbon fiber, metallic silicon and/or silicon carbide, and carbon fiber bundles that can include boron carbide upon request, in a way that they cross each other in a orthogonal fashion..

[Claim 5] The previously stated matrices are one of the Highly Oxidation Resistant Silicon Impregnated Composite Materials stated in Claim 1 through Claim 4 and have a characteristic of creating a three dimensional mesh by continuing to alternate inside the previously stated Highly Oxidation Resistant Silicon Impregnated Composite Material.

[Claim 6] One of the Highly Oxidation Resistant Silicon Impregnated Composite Material in Claim 1 through Claim 5 that has oxygen concentration levels at or below 1 percent and that has a 25% weight reduction inside a high temperature atmosphere that is maintained at 600 degrees Celsius.

[Claim 7] It is a Highly Oxidation Resistant Silicon Impregnated Composite Material made up of silicon carbide, metallic silicon, carbon essentially made from carbon fiber, and boron oxide phases. In addition, this Highly Oxidation Resistant Silicon Impregnated Composite Material has a structure made from matrices formed in and around the skeletal frame, and at least 50% of the silicon carbide are a Beta Model. In addition, the skeletal frame is made from carbon fiber bundles, Silicon-Silicon Carbonaceous Material comprised from metallic silicon and silicon carbide formed inside or around the carbon fiber bundle, and from a silicon boron oxide phase that is made and integrated as one unit with this material.

In addition, the matrices are made from 1) Silicon-Silicon Carbonaceous Series Material comprised of silicon carbide and metallic carbide, and from 2) silica boron monoxide made and integrated into the Highly Oxidation Resistant Silicon Impregnated Composite Material.
Furthermore, the previously stated matrices and the previously stated skeletal frame are made and integrated together into one unit, and the previously stated Composite Material is characterized by having a gas pocket rate of 10%.

[Claim 8] The production method of Highly Oxidation Resistant Silicon Impregnated Composite Material composed with silicon carbide, metallic silicon, carbon essentially made from carbon fiber, and boron carbide that can be included upon request. In addition, this invention makes claims a production method of a Highly Oxidation Resistant Silicon Impregnated Composite Material that possesses a structure made from matrices formed in and around the skeletal frame. Furthermore, in this invention, at least 50% of the silicon carbide are Beta Models.
This invention also pertains to the Highly Oxidation Resistant Silicon Impregnated Composite Material production method stated; a production method that has a characteristic of making a burned substance from firing a

1. yarn sequences, and/or a yarn made from carbon fiber bundles that have in them at least either metallic silicon or silicon carbide, and boron carbide that can be included upon request,

or

2. a compact substance formed by using a binder to which boron carbide that can be included upon request, at least one metallic carbon ingredient or silicon carbide ingredient,

or

3. a compact substance constructed using a binder that does not include any of the previously stated metallic silicon, silicon carbide, or boron carbide.

This invention also pertains to the Highly Oxidation Resistant Silicon Impregnated Composite Material stated above and its production method that is further characterized by the process of first adding at least one metallic silicon ingredient, silicon carbide ingredient, or boron carbide ingredient to the acquired baked substance, and while running 1NL or more of inactive gas for every 1 kg of the combined net weight of the metallic silicon and the silicon carbide on the burned substance, maintaining the internal temperature of the furnace at 1100-1400 degree Celsius and the internal pressure at 0.1 - 10hPn for more than an hour, and then raising the temperature to 1450-2500 degrees Celsius and dissolving and impregnating metallic silicon and/or silicon carbide, and boron carbide that can be included by request, and then forming a Silicon-Silicon Carbonaceous Material Phase, while at the same time integrating the boron carbide included upon request and Silicon-Silicon Carbide Series Material Phase into one unit, and upon request, making matrices from Silicon-Silicon Carbonaceous Material Phases.
This invention also pertains to Highly Oxidation Resistant Silicon Impregnated Composite Material stated above that is also characterized as being made by coating the surface of acquired baked substance with boron carbide.

This invention also pertains to the production method of the Highly Oxidation Resistant Silicon Impregnated Composite Material skeletal frame built with carbon fiber bundles, Silicon-Silicon Carbonaceous Materials formed from the silicon carbide and the metallic silicon formed inside or around the carbon fiber bundle, and boron carbide that can be included upon request.
The invention also pertains to the production method of the matrices in the Highly Oxidation Resistant Silicon Impregnated Composite Material; matrices built with Silicon-Silicon Carbonaceous Material formed from silicon carbide and metallic silicon, and boron carbide that can be included upon request.
This invention also pertains to the production method of Highly Oxidation Resistant Silicon Impregnated Composite Material in which the previously stated matrices and the previously stated frame structure are integrated together into one unit.
Furthermore, this invention also pertains to the production method of previously stated Composite Material that is a Highly Oxidation Resistant Silicon Impregnated Composite Material with a characteristic of having a gas pocket rate of 10% or less.

[Claim 9]
The production method of the Highly Oxidation Resistant Silicon Impregnated Composite Material stated in Claim 8 that has a characteristic of using carbon fiber bundles coated with thermoplastic resin.

[Detailed Explanation Of The Invention]
[0001]
[Industrial Field Of The Invention] This invention pertains to new Highly Oxidation Resistant Silicon Impregnated Composite Material that can be used as a production device for various kinds of projects that demand oxidation resistance under high temperatures, namely, melting and boiling metal, grinding, and various kinds of molding.

[0002]
[Prior Art] Following the technological innovation of each industrial field is the increasing need for material that can be used under high temperature. The reality is that there is a demand for material that can treat and process heat from metal products, glass products, and ceramic products that need to repeat a rapid heating and cooling process. There is also a demand for material light in weight, capable of being made into a desired shape, and outstanding in its ability to withstand the impact of heat, that can be used for devices for projects like melting and boiling metal, grinding and various kinds of molding. Various ceramics, carbon, and Carbon Fiber Composite Carbon Ingredients, which are referred to here as C/C Composites, are examples of material that meet these demands. However, ceramic ingredients are problematic in the fact that they are inferior in their ability to withstand the impact of heat, and break relatively easily. On the other hand, carbon and C/C Composites are superior in their ability to withstand the impact of heat, but because of the carbon ingredient, the atmosphere in which it is can be used is limited. In other words, the problem is that under circumstances in which oxygen and moisture are present, carbon and C/C Composites cannot be used at all since they will react with

the oxygen and combust. Therefore, the reality is there is not a material that combines both an outstanding resistance to the impact of heat as well as a resistance to oxidation.

[0003]
[The Issue That Invention Is Trying To Resolve]
Presenting a new Highly Oxidation Resistant Silicon Impregnated Composite Material that can be used as a tool for various projects under high temperatures, but especially more specifically, used as material that treats and process heat from metal products, glass products, and ceramic products that need to repeat the process of rapid heating and cooling, and also as material light in weight, capable of being made into a desired shape, highly oxidation resistant under high temperatures, and outstanding in its ability to withstand the impact or heat, that can be used as devices to manufacture these metal products, glass products, and ceramic products. This invention also presents the production method of the new Highly Oxidation Resistant Silicon Impregnated Composite Material stated above. Furthermore, this invention is also trying to resolve the issue of presenting a new Highly Oxidation Resistant Silicon Impregnated Composite Material with a high level of oxidation resistance that can be used for various projects, under extremely high temperatures, as well as the production method of the Highly Oxidation Resistant Silicon Impregnated Composite Material.

[0004]
As a result of the variety of studies that the original inventors undertook in order to achieve the objective stated above, they discovered that the objective stated above can be achieved through a Highly Oxidation Resistant Silicon Impregnated Composite Material that 1) is composed with silicon carbide, metallic silicon, carbon essentially made from carbon fiber, and boron carbide that can be included upon request, 2) has a structure made from matrices formed on the skeletal frame and around the skeletal frame, 3) 50% of the carbon fiber bundle are Beta Models, 4) the skeletal frame is made with carbon fiber bundles, Silicon-Silicon Carbonaceous Material that is made from silicon carbide and metallic silicon formed in and around the carbon fibers bundles, and from boron carbide that can be included upon request, 5) has matrices made with Silicon-Silicon Carbonaceous Material made by silicon carbide, metallic silicon and with boron carbide that can be included upon request, 6) the previously stated matrices and the previously stated frames are made and integrated together into one unit, and 7) the previously stated composite material has a gas pocket rate of 10% or lower, and then [they] completed this invention.

[0005] The means to resolve the issue stated in [0003] involve the following processes.
1. The process of constructing a burned substance by firing
    1. yarn sequences, and/or yarns made from carbon fiber bundles that have at least either metallic silicon or silicon carbide, and boron carbide that can be included upon request

    or

    2. compact substance was formed using a binder to which boron carbide that can be included upon request, and at least one metallic carbon ingredient or silicon carbide ingredient was added,

or

3. a compact substance that was constructed using a binder that does not include any of the previously stated metallic silicon, silicon carbide, or boron carbide.

2. The process of first adding at least one metallic silicon ingredient, silicon carbide ingredient, or boron carbide ingredient to the acquired burned substance, and while running 1NL or more of inactive gas for every 1 kg of the combined net weight of the metallic silicon and the silicon carbide on the burned substance, maintaining the temperature inside the furnace at 1100-1400 degree Celsius and the pressure inside the furnace at 0.1 -10hPn for more than an hour, and then raising the temperature to 1450-2500 degrees Celsius and dissolving and impregnating metallic silicon and/or silicon carbide , and boron carbide that can be included by request, then forming a Silicon-Silicon Carbonaceous Material Phase, while at the same time integrating together as one unit the boron carbide included upon request with Silicon-Silicon Carbonaceous Material Phase, and making matrices from Silicon-Silicon Carbonaceous Material Phases and boron carbide phases upon request.
This invention also pertains to the production method of Highly Oxidation Resistant Silicon Impregnated Composite Material stated above that has a characteristic of being made by coating the surface of acquired baked substance with boron carbide.
Therefore, inventors of this invention produced the previously stated Highly Oxidation Resistant Silicon Impregnated Composite Material and thus completed this invention.
Furthermore, in this invention is presented a Highly Oxidation Resistant Silicon Impregnated Composite Material that has a silicon boron carbide phase formed in at least one section of the Composite Material stated above.

[0006]
The Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention is essentially comprised by 25%-65% carbon in weight, 1% - 10% metallic silicon in weight, 10%-50% silicon carbide in weight, and 0% - 10% boron carbide in weight. At the very least the matrices made from the Silicon-Silicon Carbonaceous Material and boron carbide will be arranged in a three dimensional manner. In between the Yarn aggregations made from carbon fiber that have been integrated into one unit to prevent separation from each other, these matrices are integrated together as one unit. Of course, boron carbide is a random constituent, but in order to further strengthen the oxidation resistance, it is desirable to have at least 0.1% of boron carbide in weight. By the way, as will be mentioned later, in order to form a Silicon-Silicon Carbonaceous Material, it is desirable that the thickness of the Silicon-Silicon Carbonaceous Material to be at least 0.01mm. It is further desirable that the thickness of the Silicon-Silicon Carbonaceous Material is at least 0.05mm or more, and it is most desirable for the thickness of the Silicon-Silicon Carbonaceous Material to be at least 0.1mm or more.

[0007] The carbon mentioned above is essentially made from carbon fiber. To be essentially made from carbon means that a miniscule amount of isolated carbons of graphite quality that formed on the surface of substances that originated as auxiliary materials such as binders, or carbon fiber itself, can be included. However, the carbon

forming the skeletal frame is, generally speaking, comprised from carbon fibers. Furthermore, regarding the new Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention, it is desirable that the silicon concentration rate rise as the previously stated matrices get further away from the previously stated yarn. In addition, the Highly Oxidation Resistant Silicon Impregnated Composite Material stated above is controlled so that the gas pocket rate is 10% or lower, but desirably between 0.5%-3%.

[0008]
[The Configuration Of The Enactment Of The Invention] The Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention is made from carbon fiber bundles, Silicon-Silicon Carbonaceous Material made with silicon carbide and metallic silicon made inside and around the carbon fiber bundle. It is also made with skeletal frames that are formed with boron carbide that can be included upon request, and Silicon–Silicon Carbonaceous Material made of silicon carbide and metallic silicon. In addition, the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention is also made from matrices formed from boron carbide that can be included upon request. In addition, the previously stated matrices and the previously stated skeletal section are made and integrated into one unit.
Furthermore, the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention is formed from composite material made with carbon and ceramics that have a stoma rate of 10% or lower.

[0009] As stated above the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention is comprised from silicon carbide, metallic silicon, carbon essentially made from carbon fiber, and boron carbide that can be included upon request. In addition, Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention has a structure made of matrices formed in and around the skeletal frame, and is a Composite Material that has matrices made from boron carbide that can be included upon request, Silicon-Silicon Carbonaceous Material that is composed from silicon carbide and metallic silicon, a skeletal frame made from boron carbide that can be included upon request, Silicon-Silicon Carbonaceous Material made from metallic silicon and boron carbide formed inside and around the carbon fiber bundle, and carbon fiber bundles. This Highly Oxidation Resistant Silicon Impregnated Composite Material may have a silicon boron oxide phase in one section.

[0010]
It is desirable for the skeletal frame to be a compact model that was acquired by including powdered phenol (when needed) and a powdered binder in the carbon fiber bundle, then adjusting the carbon fiber bundle to make a soft coating of plastic from thermoplastic resin around the carbon fiber bundle, then acquiring a pre-formed yarn as a soft intermediate material, then making this pre-formed yarn into a sheet or fabric like form using the method described in Laid Open Japanese Patent Publication 2-80639, then laminating the necessary amount of these sheet and fabric like pre-formed yarns, and making a Hot Press. Of course, a baked substance that was acquired through firing the compact model above can be used as well. In this case, a binder is a fine powdered

ingredient that serves as matrices for the compact objects or the baked substances that are made from the carbon fiber bundles in which metallic silicon, and/or the silicon carbide have not yet been impregnated. After the firing, it refers to substances that include the Pitch, and Corks, which are, in respect to the carbon fiber bundles, isolated carbons.

[0011] In this detailed statement, a C/C Composite refers to something that is acquired by regularly binding together several hundred to several tens of thousands of carbon fibers with a radius of around 10 nm and forming a fiber bundle (yarn), and then insulating the fiber bundle with thermoplastic resin to adjust the pre-formed yarn, and then making this into a sheet or fabric like form fabric through the method described in Laid Open Japanese Patent Publication 2-80639, and then lining up the sheet or fabric-like substance in a two dimensional or three dimensional direction and making all the sheets face one direction (a UD sheet) or making each one of them cross with each other, and furthermore, forming an alternative compact object (pre-formed fiber) with a predetermined shape by laminating the cross and the sheet stated above, and then firing the thermoplastic resin coating made from organic matter formed around the outside of the fiber bundles in the said pre-formed compact object, then removing carbon from the same coating stated above. Furthermore, in this detailed statement, Laid Open Japanese Patent Publication 2-80639 will be cited for references. Regarding the C/C Composite pertaining to this invention, it is desirable for the carbon components other than carbon fiber inside the yarn to be a carbon powder, and it is especially desirable for the carbon components other than carbon fiber inside the yarn to be graphitized carbon powder.

[0012] When adjusting the pre-formed yarn, as long as at least metallic silicon or silicon carbide, and boron carbide that can be included upon request are mixed together in specified quantities, a phase can be made of Silicon-Silicon Carbonaceous Material and boron carbide that can be included upon request can be formed inside the yarn. When adjusting the Sheet or the Cross from the pre-formed yarn, as long as at least metallic silicon or silicon carbide, and boron carbide that can be included upon request are mixed together in specified quantities, a phase made of Silicon-Silicon Carbonaceous Material, and boron carbide that can be included upon request, can be formed on surface of the yarn. For mixing procedures, there is the method of directly incorporating the metallic silicon and/or the silicon carbide as well as the boron carbide upon request into the spaces between carbon fiber and carbon fiber making up a yarn, or into the spaces between the yarns. There is also an indirect method of incorporating the metallic silicon or silicon carbide, and boron carbide that can be included upon request, with the assisting matter that is used when adjusting the binder, the yarn from the phenol resin, the yarn sequence, or when laminating the yarn sequence and adjusting the sheet or the cross. In order to incorporate everything equally, the indirect incorporating method is best.

[0013] The amount of metallic silicon and/or silicon carbide used will vary according to the design and performance of the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention, but normally, it is sufficient for the amount of metallic silicon and/or silicon carbide used to be between 11%-60% of the total weight of the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention. Furthermore, as for the amount of the boron carbide that can

be included upon request, it is within 0-10% of the total weight of the Highly Oxidation Resistant Silicon Impregnated Composite Material. Of course, since phases made from Silicon-Silicon Carbide Series Material and boron carbide that can be included upon request just need to be formed at least as matrices, you do not have to impregnate these materials inside the yarn or on the surface of the yarn according to the performance requirements of each use.

[0014] Concerning the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention, as ingredients comprising the skeletal frame, carbon fiber bundles formed from multiple carbon fibers, or desirably, carbon fiber bundles that are like the C/C Composite stated above, are used. Silicon-Silicon Carbonaceous Material and boron carbide that can be included upon request are formed on the surface and/or the interior of the carbon fiber that comprises each yarn. However, it is necessary that among the carbon fibers that form each carbon fiber bundle, at least one carbon fiber section preserve its structure as carbon fiber and not be destroyed by any reaction to metallic silicon and/or a silicon carbide. Through this preservation, the innate mechanical strength of the carbon fiber can be just about fully preserved. Therefore, for carbon fiber, it is desirable to have a C/C Composite structure where at least one carbon fiber section can easily remain without silicon carbonizing. Moreover, the carbon fibers have a structure where the matrices made from Silicon-Silicon Carbonaceous Material and from boron carbide that can be included upon request, are formed on the inside of the carbon fiber bundle and in the spaces between the adjoining yarns in the yarn aggregation, and thus, the oxidation resistance is strengthened.

[0015] In this invention, Silicon-Silicon Carbonaceous Material is a generic term for ingredients in which silicon and silicon carbide are the main elements. The Silicon-Silicon-Carbonaceous Material referred to in this case, is formed by reacting to carbon fiber and metallic silicon, or with carbon silicon that is formed when producing the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention. If, for example, a compact body is acquired by using a binder to which metallic silicon and/or silicon carbide have/has been added, to join together two yarn sequences made from carbon fiber bundles, and then carbonizing this compact body at 700 -1200 degrees Celsius, and furthermore firing this compact body at 1500-3000 degrees Celsius, then in at least one section formed with carbon fibers and isolated carbons on the surface of the carbon fiber reacting with metallic silicon and/or carbon silicon, and the phase essentially made from silicon carbide and the phase in which metallic silicon remain non-reactive both change continuously, this is the ingredient for which Silicon-Silicon Carbonaceous Material is a generic term.

[0016] In other words, Silicon-Silicon Carbide Series Material has several different kind of phases, beginning with silicon phases made from silicon still remaining in a non-reactive state, all the way through silicon carbide that is almost pure. Typically speaking, this Silicon-Silicon Carbonaceous Material is made from a silicon phase and a silicon carbide phase. However, a silicon carbide phase has a Silicon Carbon coexistence phase in which the amount of silicon contained changes in a gradient slope like manner.

Therefore, as described above, regarding Silicon-Silicon Carbonaceous Series, Silicon-Silicon Carbonaceous Material is a generic term for ingredients that have a carbon concentration rate within a 0mol%--50mol% range. Concerning the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention, Silicon-Silicon Carbonaceous Material can be formed in the matrices section, as well as inside the carbon fiber bundle and/or the surface of the carbon fiber bundle.

[0017] Further, it is desirable for this Highly Oxidation Resistant Silicon Impregnated Composite Material to have matrices with a silicon content ratio that increases the further the distance from the surface of the yarn. In addition, regarding this Highly Oxidation Resistant Silicon Impregnated Composite Material, it is desirable that the yarn aggregations be formed with multiple yarn sequences, and that each yarn sequence be formed with yarn that was made by binding a specific numbers of carbon fibers, and lining them up in an almost parallel and two dimensional fashion. In addition, regarding this Highly Oxidation Resistant Silicon Impregnated Composite Material, it is desirable that the yarn aggregation is made through laminating each yarn sequence. This will allow for the Highly Oxidation Resistant Silicon Impregnated Composite Material to have a laminated structure in which multiple layers of yarn sequences are laminated in a specific direction.

[0018] Regarding the strength of the matrices in these circumstances, it is especially desirable that the longitudinal direction of each yarn in the sequence of adjoining yarns intersect with each other, because this will further accelerate the dispersion of stress. It is especially desirable that the longitudinal direction of the yarns in the sequence of adjoining yarns be perpendicular to each other. Furthermore, it is desirable that matrices occur in succession inside the Highly Oxidation Resistant Silicon Impregnated Composite Material, and thus form a three dimensional mesh. In these circumstances, it is especially desirable for a three dimensional lattice to be formed by matrices in each yarn sequences being lined up in an almost parallel manner and two dimensional manner, and matrices generated inside each adjoining yarn sequence occurring in succession. Furthermore, it is fine for gaps between the adjoining yarns to be completely filled with Matrices, but these circumstances also include when just one section of the gaps between each yarn is filled with matrices.

[0019] Concerning the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention, it goes without saying that Silicon-Silicon Carbonaceous Material and the boron carbide that can be included upon request along the surface of the yarn as matrices, just as shown in figure 2. In addition, concerning the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention, a phase made from Silicon-Silicon Carbonaceous Material and boron carbide that can be included upon request can be formed in the inside on the carbon fiber bundle and/or on the surface of that same carbon fiber bundle. In the matrices, and/or inside the carbon fiber bundle, and/or on the surface of the carbon fiber bundle, carbon that can be included upon request will integrate as one unit with the Silicon-Silicon Carbonaceous Material, or, be independent and be like scattered islands in an ocean of Silicon-Silicon Carbonaceous Material. As stated above, since the standard skeletal frame section of

composite fibers is strengthened by the Silicon-Silicon Carbonaceous Material and the boron carbide that can be included upon request, the oxidation resistance is strengthened as well. It is desirable to include boron carbide since boron carbide can dramatically increase the oxidation resistance of a composite fiber's standard skeletal frame section under high temperatures. Even more desirable from the perspective of increasing the oxidation resistance quality, is that boron carbide phases form on the maximum surface of the Highly Oxidation Resistant Silicon Impregnated Composite Material that pertains to this invention.

[0020] The Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention is a Composite Material made from the following 1 and 2.
1. A skeletal frame made from three dimensional C/C Composites made from Yarn aggregations built by laminating Yarn Sequences formed in the Silicon-Silicon Carbonaceous Material phase on the inside and/or the surface of carbon fiber bundle in which a specific number of Yarns that can be formed on the Silicon-Silicon Carbonaceous Material phase are lined up.

2. Silicon-Silicon Carbonaceous Material that forms three-dimensional lattice-like matrices in the gaps between the yarns that compose the same skeletal frame mentioned in 1. Under normal temperatures, the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention has a kinetic friction coefficient between 0.1-0.5. By placing on the surface, a matrix layer made from Silicon-Silicon Carbonaceous Material that has oxidization resistance, creep resistance, and spooling resistance, the low oxidization resistance of C/C Composite can be overcome, and in the presence of oxygen and under high temperatures, it is possible to use them as bendable materials, and as Braking materials that can easily be refined.

[0021] Since the gas pocket rate is kept at 10% or lower, but desirably between 0.5% and 3%, kinetic friction coefficient variations brought about by changes in the surrounding environment are extremely small, and a stable brake performance can be achieved. In high temperatures, abrasion and wear at 500 degrees Celsius is 1.0%/hour or lower, but even more desirable for this rate to be 0.6%/hour or lower. Furthermore, the gas pocket has an abrasion and wear resistance quality that has adopted the outstanding abrasion and wear resistance qualities found originally in silicon carbide. In addition, the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to the invention displays an outstanding resistance to oxidization, even inside atmospheres being kept at high temperatures of 600 degrees Celsius. In other words, in high temperature atmospheres, like the one stated above, with 1% oxygen, the weight reduction amount is 25% or less; in high temperature atmospheres, like the one stated above, with 1,000 ppm of oxygen, the weight reduction is 3% or less; and in high temperature atmospheres, like the one state above, with 100 ppm of oxygen, and the weight reduction amount is essentially zero, and the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention displays an extremely high oxidation resistant quality. As stated above, this is thought to be something caused by Silicon-Silicon

Carbonaceous phases forming not only in the matrices section, but also in the inner section and/or the surface of the carbon fiber.

[0022] Concerning the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention, Silicon –Silicon Carbonaceous Material Phases not only form matrices, but since the Silicon-Silicon Carbonaceous Material Phases are formed on the inside and/or the surface of the yarn and/or the yarn sequence, the speed that Silicon-Silicon Carbonaceous Material dissolves and becomes glass and protects the skeletal frame from oxygen, is faster than the rate in which oxygen disperses towards the inside of the skeletal frame, oxidation of carbon fiber used as a skeletal frame by dispersed oxygen can be avoided, and the skeletal frame can be protected from the oxidation. Therefore, since the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention displays a self repairing quality, it can be used over a much longer period of time. This phenomenon is clearer when boron carbide is included. The reason behind this is not yet definite, but it may be because of Grazing, in which oxygen, boron carbide, silicon carbide and/or metallic silicon are simultaneously oxidized, and a glass phase made from boron oxide and silica is formed on the surface of the carbon fiber, and wraps that surface.

[0023] As opposed to when only silicon carbide and/or metallic silicon is used, it is speculated that when boron carbide is also combined and included, boron carbide is oxidized at the same time, and the Glazing is accelerated. Therefore, the Highly Oxidation Resistant Silicon Impregnated Composite Material can be used as various types of molding material that are needed when processing metal products, glass products, and ceramic products that need to repeat rapid temperature increases and rapid cooling. Or the Highly Oxidation Resistant Silicon Impregnated Composite Material can be used as material to produce these metal, glass, and ceramic products that need to repeat rapid temperature increase and rapid cooling.

[0024]
Composite members pertaining to this invention that have already gone through grazing process stated above, and thus do not have to go through it again, are Highly Oxidation Resistant Silicon Impregnated Composite Materials made up of silicon carbide, metallic silicon, carbon essentially made with carbon fiber, and silicon boron oxide. In addition, this Oxidation Resistant Silicon Impregnated Composite Material has a structure made from matrices that have been formed in and around the skeletal frame, and at least 50% of the silicon carbide in this Highly Oxidation Resistant Silicon Impregnated Composite Material are Beta Models. In addition, the frame is made from carbon fiber bundles, Silicon-Silicon Carbonaceous Ingredients comprised from metallic silicon and silicon carbide that formed inside or around the carbon fiber bundle, and silicon boron oxide phases made and integrated into this material as one unit.
In addition, the matrices are made from --1) Silicon-Silicon Carbonaceous Series Material made with silicon carbide and metallic carbide, -- 2) silica boron monoxide

made and integrated into the Highly Oxidation Resistant Silicon Impregnated Composite Material.
Furthermore, the previously stated matrices and the previously stated skeletal frame are made and integrated into one unit, and the previously stated Composite Material is characterized by having a gas pocket rate of 10%.

[0025] Of course it is possible to make this Oxidation Resistant Silicon Impregnated Composite Material by having the matrices forcibly accelerate the oxidation of the Oxidation Resistant Silicon Impregnated Composite Material formed from Silicon-Silicon Carbonaceous Material made with silicon carbide, metallic silicon, and boron carbide that can be included on request. Here, being integrated into one unit does not necessarily only mean both objects are one harmonious body. Even if both objects are independently recognized, as long as both objects do not easily separate from a weak mechanical impact, the two objects will be considered integrated into one unit. Therefore, it also includes the condition in which the boron carbide is like are like bunch of islands in an ocean of Silicon- Silicon Carbonaceous Material.

[0026] Furthermore, since Highly Oxidation Resistant Silicon Impregnated Composite Material uses yarn aggregates made from carbon fiber bundles as the basic structure for its skeletal frame, it can meet the demands for being a lightweight, energy conserving material. Shape abnormalities will not be generated since the length of the carbon fiber will not shrink even after the matrices are formed, the mechanical strength is preserved, and the longitudinal directions of each yarn of the yarn aggregation will cross each other, desirably at right angles. The matrices made from isolated carbons in the skeletal frame are rich in uniformity. Therefore, Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention produced through impregnating metallic Silicon into these matrices, will equally disperse the metallic silicon, and react with the carbon, so that the composition of the substances that form the Oxidation Resistant Silicon Impregnated Composite Material are dispersed equally throughout a specific volume. Therefore, it is difficult for the shape to change even when fired, and large scale molds with complicated shapes, as well as thin large scale molds that have complicated shapes can be manufactured as well.

[0027] Furthermore, since the skeletal frame is a carbon fiber bundle, it is highly limber, has superior impact resistance, and very hard. Therefore, it became possible to improve carbon fibers resistance to abrasion under high temperatures, while keeping the special qualities of the conventional carbon fibers. In addition, since a succession of open gas pockets are formed between yarn made from carbon fiber bundles, the phase formed from boron carbide that can be included upon request, and the Silicon-Silicon Carbonaceous Material of the matrices made by impregnating metallic silicon and/or silicon carbide, and upon request, boron carbide into this gas pocket, are structured successively and have a three dimensional mesh structure. Therefore, no matter which section is cut out, by the side of the carbon fiber that became the skeletal frame structure, it a high resistance to wear and

abrasion, and the high heat releasing qualities and the high flexibility of the carbon fiber will be maintained.

[0028] Regarding the structural characteristics of the Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention, for the sake of simplifying the explanation, substances formed only by Silicon-Silicon Carbonaceous Material will be used for an example, and diagrams will be used for further explanations. Diagram 1 is a schematic perspective view that will explain the skeletal frame of the Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention. Regarding Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention, Diagram 2 is a cross section diagram that explains the formation stage of the Silicon-Silicon Carbonaceous Material by displaying a cross structure that has omitted one structure of the Composite Members pertaining to one mode of the Silicon-Silicon Carbonaceous Material.

[0029] As displayed in Diagram 1, the skeletal frame of Oxidation Resistant Silicon Impregnated Composite Material 7 is comprised from yarn aggregation 6. Yarn aggregation 6 is made by vertically laminating yarn sequence 1A, 1B, 1C, 1D, 1E, and 1F. In each yarn sequence, each yarn 3 is lined up in a two dimensional manner, and the longitudinal direction of each yarn is roughly parallel to other yarns. The longitudinal direction of each yarn in yarn sequences that are vertically next to each other, are at right angles to each other. In other words, the horizontal direction of each yarn 2 of each yarn sequence 1A, 1C, and 1E are parallel to each other, and the horizontal direction of each yarn 2A in each yarn sequence 1B, 1D, and 1F are at right angles to each yarn 2A in each yarn sequence 1B, 1D, and 1F. Each yarn is made from fiber bundle 3, which is made from carbon fiber, and carbon elements other than carbon fiber. The three dimensional lattice like yarn aggregation 6 is made when the yarn sequences are laminated. Each yarn will be compressed during the process of pressurized shaping and will basically become an ellipse.

[0030] In each yarn sequence 1A, 1C, and 1E, matrix 8 fills the gaps between adjoining yarns, and each matrix 8 is stretched parallel to the surface of yarn 2. In the case of each yarn sequence 1B, 1D, and 1F, a separate matrix 8 is formed in the gaps between adjoining yarns, and this matrix 8 is stretched parallel to the surface of yarn 2 B. As shown in Diagram 2, when the matrix 8 made from the Silicon-Silicon Carbonaceous Material is formed, it insulates the surface of each yarn. In addition, in the mode shown in Diagram 2, regarding the inside the composite member, Silicon-Silicon Carbonaceous Phases are formed on the inside of the yarn made of carbon fiber bundles.

[0031] Each matrix 8 is long and narrow along the surface of each yarn, and desirably extends as a straight line, and intersects at a right angle with other matrix 8 (matrix 8's). In addition, the matrix 8 of yarn sequence 1A, 1C, and 1E, and the matrix 8 of the yarn sequence 1B, 1D, and 1F at right angles with the matrix 8 in yarn sequence 1A,1C, and 1 E, both occur repeatedly in the gaps between each yarn

2A and yarn 2B. As a result, overall, matrix 8 forms a three dimensional lattice. Concerning the Silicon-Silicon Carbonaceous Material Phase, it is desirable for the silicon concentration to be higher the further the distance for the surface of the adjoining fibers. For material used for brakes or grinding, it is desirable that the surface of Highly Oxidation Resistant Silicon Impregnated Composite Material be formed from Silicon-Silicon Carbonaceous Material Phases.

[0032] It is desirable that the matrix layer formed by impregnating the Silicon-Silicon Carbonaceous Material into the fired body have a thickness of at least 0.01 mm or more. It is more desirable that this matrix layer be at least 0.05mm or thicker, and it is all the more desirable if the thickness of this matrix layer is at least 0.11mm or more. These matrix layer thickness levels are desirable since a matrix layer thickness of 0.1mm or less would not provide the resistance that a sliding member would need in high oxidation circumstances.

[0033] In addition, concerning the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention, it is desirable that the concentration inside the Silicon-Silicon Carbonaceous Material phase of silicon joined with carbon get lower the further away from the surface of the adjoining carbon fiber and the closer towards the interior of the adjoining carbon fiber. By making silicon concentration slope in the matrices, or the interior/and or the surface of the yarn and/or the yarn sequence, the strength and corrosion resistance in atmospheres of strong oxidation and corrosion are improved. The deficiency healing function of the inner and surface layer can be considerably improved as well. In addition, the thermal stress deterioration of material caused by the difference in the heat expansion coefficients can be prevented because the silicon concentration in the surface layer is relatively higher than the silicon concentration in the inner layer, and the micro cracks are fixed while being heated, and the acid resistance is maintained. This invention includes the aspect of Silicon-Silicon Carbonaceous Material Phases formed in the interior and/or the surface of the yarn and/or the yarn sequence. However, by including this aspect, even if a larger-than-expected abnormal amount stress is added and one section of the carbon is exposed to the surface, the Silicon-Silicon Carbonaceous Phases formed in the interior and/or on the surface of the yarn and/or the yarn arrangement display a self-repair quality.

[0034] In addition, the boron carbide that can be included in the Highly Oxidation Resistant Silicon Impregnated Composite Material of this invention have the ability to lubricate. Therefore, by including this boron carbide in the skeletal frame made from carbon fiber, the lubricity of the fiber in the skeletal frame of the Silicon-Silicon Carbonaceous Material can be maintained, and the decline of the softness can be prevented as well. Furthermore, for example, in respect to 100% of the weight of the skeletal frame made from carbon fiber, it is desirable for the amount of boron carbide included in the skeletal frame made from carbon fiber to be 0.1 -10% of the weight in comparison to 100% of the weight of this skeletal frame made from carbon fiber. The following is the reason the range of 0.1-10% is desirable.

1. When the boron carbide weight percentage is less than 0.1% by weight, lubrication from boron carbide is not sufficient.
2. When the boron carbide weight percentage is more than 10% by weight, the fragility of the boron carbide begins to appear in the Highly Oxidation Resistant Silicon Impregnated Composite Material.

[0035] Since this kind of Highly Oxidation Resistant Silicon Impregnated Composite Material has shock resistance, high solidity and lightweight qualities of C/C Composites, and acid resistance, sporing/sparing resistance, self-lubrication, and abrasion resistance of Silicon-Silicon Carbonaceous Material, in addition to a self repair quality, this kind of Highly Oxidation Resistant Silicon Impregnated Composite Material can withstand long periods of use under high temperatures and high oxidation conditions, and therefore is suitable for use as a sliding member or, as material for brakes.

[0036] The Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention can be produced, desirably, through the method explained in detail below.

1.The process of using either using a binder that does not include any of the previously stated boron carbide, silicon carbide, or metallic carbide, or a binder to which boron carbide that can be included upon request, and at least one metallic silicon ingredient or silicon carbide ingredient have been added, to make yarn, and/or a yarn sequence made from carbon fiber bundles of carbon fiber that can have boron carbide that can be included upon request, and at the very least a metallic silicon ingredient or a silicon carbide ingredient attached to the inside of the carbon fiber.

2. The process of first adding at least one metallic silicon ingredient, silicon carbide ingredient, or boron carbide ingredient to the acquired fired body, and while running 1NL or more of inactive gas for every 1 kg of the combined net weight of the metallic silicon and the silicon carbide on the fired body, maintaining the internal temperature of the furnace at 1100-1400 degree Celsius and the internal pressure of the furnace at 0.1 -10hPn for more than an hour, then dissolving and impregnating silicon carbide and metallic silicon to the inside of the open gas pocket of the previously stated fired body, and while forming Silicon-Silicon Carbonaceous Phases, dispersing boron carbide upon request throughout the Silicon-Silicon Carbonaceous Material phase and thus allowing for the formation of matrices made from boron carbide that can be included upon request and Silicon-Silicon Carbonaceous Material.

3. Further laminating the acquired fired body with boron carbide.

[0037] First (1), the Highly Oxidation Resistant Silicon Impregnated Composite Material can also be produced through the process of forming a fired body in which

the inside, and/or the surface of the yarn surface have boron carbide that can be included upon request, and at the very least one type of metallic silicon ingredient or silicon carbide ingredient added to it. This fired body in which boron carbide that can be included upon request and at the very least one type of metallic silicon ingredient or silicon carbide ingredient are added the inside, and/or the surface of the yarn, is made by using a binder that has boron carbide that can be included upon request and at least one metallic silicon ingredient or silicon carbide ingredient added, to make yarn sequences formed from lines of yarn, and/or to form yarn made from carbon fiber bundles in which boron carbide that can be included upon request, and at least one metallic silicon ingredient or boron carbide ingredient are added inside the carbon fiber.

[0038]Secondly (2), Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention can also be produced through the following processes.

1. The process of using a binder that does not include any boron carbide, silicon carbide, or metallic silicon to make yarn and/or yarn sequences formed from carbon fiber bundles whose carbon has inside it at least one type of material from metallic silicon and the silicon carbide, and boron carbide that can be included upon request, and then firing this compact body.

2. The process of dispersing boron carbide that can be included upon request to the Silicon-Silicon Carbonaceous Material Phase and thus forming matrices from Silicon-Silicon Carbonaceous Material Phases and boron carbide that can be included upon request, At the same time, adding metallic silicon, and/or silicon carbide, and boron carbide upon request to the acquired fired body, then, after running 0.1NL or more of inactive gas for every 1 kg of the combined net weight of the fired body and all the metallic silicon and silicon carbide inside the fired body, maintaining the internal furnace temperature at 1100-1400 degrees Celsius, and the internal furnace pressure at 0.1-10hPa.

When boron carbide is not included, the temperature for melting and impregnating should be between 1700 degrees Celsius and 1800 degrees Celsius.

[0039] Thirdly (3), concerning the Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention can also be produced through the following processes.

1. The process of making a burned substance through the method laid out in (1) of [0037]

2. Adding metallic silicon and/or silicon carbide, and boron carbide when requested using the same method laid out in (2) of [0038], then running 0.1 NL or more of inactive gas for every 1kg of the combined net weight of the fired body, all the metallic silicon inside the fired body and all the silicon carbide inside the fired body, while at the same time maintaining the furnace internal temperature at 1100-1400

degrees Celsius, and the furnace internal pressure at 0.1-10hPa. After this, raising the temperature to 1450-2500 degrees Celsius and melting and impregnating boron carbide that can be included upon request, metallic silicon, and/or silicon carbide, into the gas pocket of the previously stated baked substance. At the same time, matrices should be made from Silicon-Silicon Carbonaceous Phases by dispersing boron carbide that can be included upon request to the Silicon-Silicon Carbonaceous Material Phase.

[0040] Fourthly (4), the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention can also be made by using boron carbide to spray and cover the surface of the object acquired through any of the methods stated above. Furthermore, the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention can be made by using a compact object that was made by building a laminated body from sheet and fabric shaped pre-formed yarn acquired by coating carbon fiber bundles with plastic from thermoplastic resin using the method stated in Laid Open Japanese Patent Publication 2-80639. Or, it can a fired body of the compact substance state above in (4), or in other words a C/C Composite. In the case of the C/C Composite, metallic silicon, and/or silicon carbide, and requested boron carbide can be added to the inside of the carbon fiber or the binder. Furthermore, metallic silicon, and/or silicon carbide, and requested boron carbide can be added to the fired body. Concerning the method of adding metallic silicon, and/or silicon carbide, and requested boron carbide to the inside of the carbon fiber, no matter which method you use, there are not any particular restrictions. There should be no problems if the adding is done according to what is most appropriate for that time.

[0041] Next, concerning the production method stated above in (2), C/C Composites will be used as an example to further explain the production method stated above in (2). A carbon fiber bundle is made by including, in the bundle of carbon fibers, a powdered binder pitch and corks items which will end up as matrices, and furthermore including powdered phenol resin as needed. A pre-formed yarn is acquired by using plastic from thermoplastic resin to form a flexible coating around the carbon fiber bundle. The compact object is acquired by making this pre-formed yarn like a yarn, and after laminating the necessary amount of this yarn, shaping this yarn in a 300-2000 degrees Celsius Hot Press, and in an atmosphere that has a pressure level that falls between normal pressure and 500kg per square centimeter. It is also possible to carbonize this fired body at temperatures between 700-1200 degrees Celsius, and graphitize it at a temperature between 1500 and 3000 degrees Celsius.

[0042] The carbon fiber can be any PAN series carbon fiber acquired by carbonizing acrylonitrile copolymer fiber, and Pitch series carbon fibers, both or which were made by using Petroleum Pitches or Coal Tar Pitches as basic ingredients to adjust, melt spin, make infusible, and carbonize pitches used for spinning. As for the carbon precursors necessary for the formation of the matrices, the thermosetting resin, tar,

and pitch, from phenol resin and epoxy resin can be used, but corks objects and organic compounds can be included as well.

[0043] Next, the fired body manufactured in the way stated above, at least the metallic Silicon or Silicon carbide, and boron carbide that could be added upon request in are kept in a temperature range of 1100-1400 degrees Celsius, and an internal oven pressure between 0.1-10hPa. The holding time will vary according to a variety of factors, but there should be no problem as long as there is enough time to remove from the firing atmosphere gasses like CO that emerge as a result of the change from inorganic polymer toward inorganic ceramics, or there is enough time to prevent the firing atmosphere from being polluted by outside substances in the air such as O2. In addition, it is desirable to form phases made from Silicon-Silicon Carbonaceous Material and boron carbide that can be included upon request on the surface of the fired body when running 0.1NL (Normal Liter: When the temperature is 1200 degree Celsius, and the pressure is 0.1hPa, this is equivalent of 5065 liters) or more of inactive gas for every 1kg of silicon and the compact body, or for every 1kg of silicon and the fired body. Next, the temperature is raised to between 1450-2500 degree Celsius, and while making Silicon-Silicon Carbonaceous Material by melting and impregnating the carbon that can be included upon request, silicon, and/or carbon into the inside of the open gas pocket of the previously stated fired body, integrate the boron carbide that can be included upon request into one unit with the Silicon-Silicon Carbonaceous Material Phase, and form a phase made from boron carbide that can be included upon request and Silicon-Silicon Carbonaceous Material. When boron carbide is not included, it is desirable for the temperature of melting and impregnating to be 1700-1800 degrees Celsius.

[0044] It is desirable for the fired body, at the very least metallic silicon or carbon silicon, and boron carbide that can be added upon request to be kept between a temperature of 1100-1400 degrees Celsius and at a pressure between 0.1-10hPa for one hour or more, and at the same time, managing a flow of 0.1NL or more of inactive gas for every 1 kg of combined weight of the fired body, the metallic silicon, and the silicon carbide. It is even more desirable to have 10 NL of inactive gas flowing for every 1 kg of combined weight of the fired, the metallic silicon, and the silicon carbide. By making an atmosphere in which inactive gas is present during the firing process, (in other words, the stage before the boron carbide that has been added upon request, and at least metallic silicon or silicon carbide have been melted and impregnated), gasses such as CO that are generated as a result of inorganic polymer or other inorganic material becoming ceramic material, can be removed from the firing atmosphere. In addition, by preventing the firing atmosphere from being contaminated by gasses in the air such as O2, composite material made after that point by melting and impregnating material such as the metallic silicon and the silicon carbide stated above, can have a low rate of gas pockets.

[0045] When dissolving or impregnating boron carbide that can be included upon request, metallic silicon, and/or silicon carbide into the fired body, the atmosphere temperature should be raised to 1450-2500 degrees Celsius. In this case, it is

desirable for the firing furnace pressure to be in the range of 0.1-10 hPa. When boron carbide is not included, the desirable temperature for melting and impregnating is 1700-1800 degree Celsius.

[0046] As stated above, through coating of the carbon fiber bundle (yarn) with soft materials such as thermoplastic resin, and the combination of impregnating and dissolving silicon and/or the silicon carbide, the said soft materials will pyrolytically decompose and leave a long and narrow open gas pocket in the fired body, and through this narrow opened gas pocket, it will be easier for the silicon and/or the silicon carbide to permeate deep inside the fired object.. In this process of permeation, the Silicon and/or the Silicon carbide will react with the carbon in the yarn, and will gradually carbonize at the yarn's surface, and the Highly Oxidation Resistant Silicon Impregnated Composite Material used in this invention will be made. Yet, depending on how the Highly Oxidation Resistant Silicon Impregnated Composite Material will be used, it is fine to form what could be referred to as a Highly Oxidation Resistant Silicon Impregnated Composite Material Layer, in only one section of a surface layer on the skeletal frame made from C/C Composite Of course, it is fine to form a layer of boron carbide by spraying silicon, and/or silicon carbide on the surface.

[0047] Adjusting the thickness of the phase made from Silicon-Silicon Carbonaceous Material and boron carbide that can be included upon request that both construct the matrix layer, is done according to the rate of open gas pockets and the diameter of the pores. For example, when the phase made from Silicon-Silicon Carbonaceous Material and boron carbide that can be included upon request is 0.01-0.10 mm, the rate of gas pockets near the surface of the compact body or the fired body should be between 5-50%, and the average diameter of the pore should be 1 nanometer or more. It is desirable for the rate of gas pockets in the compact body or the fired body to be between 10-50%, and it is desirable for the average diameter of the pore to be 10 um or more. The reason these rates are desirable is because if the rate of gas pockets is below 5%, the binders of these compact bodies or the fired bodies cannot be completely removed. In addition, if the rate of gas pockets is above 50%, the Silicon-Silicon Carbonaceous Material will impregnate and form deep inside the skeletal frame, and the shock resistance of the composite material will decline.

[0048] Furthermore, in order to form a Highly Oxidation Resistant Silicon Impregnated Composite Material Layer only on the carbon fiber bundle surface, it is desirable to use a compact body adjusted in a way where the rate of open gas pockets near the surface is at least 0.1-30% while the firing is taking place. In other words, it is fine as long as the thickness is adjusted in respect to the carbon fiber bundle coating the soft intermediate material made from organic material that will decompose under heat (pyrolytically decompose).

[0049] In order for the rate of gas pockets in the compact body or in the fired body to decrease the further away from the surface of the compact body or the baked

substance and increase the closer towards the inside of the compact body or the baked substance, the multiple pre-formed sheets made from separate pre-formed yarns in binder pitches must be placed in a way that the binder pitch gets bigger as it moves from the inside of the compact body, or the baked substance towards the surface layer of the compact body or the baked substance.

[0050] Furthermore, when creating a silicon density gradient of the phase made from Silicon-Silicon Carbonaceous Material and from boron carbide that can be included upon request stated above, the composite material should be produced using either a fired body that has been adjusted so that the rate of open gas pockets near the surface decreases the further away from the surface and the closer towards the inside of the phase, or a compact body that is adjusted in a way in which, at the very least, while the firing is taking place, the rate of open gas pockets near the surface will get smaller the further away from the surface and the closer toward the inside of the phase. When impregnating boron carbide that can be included upon request, and at least metallic silicon or silicon carbide into the fired body, the rate of gas pockets in the Highly Oxidation Resistant Silicon Impregnated Composite Material can easily be kept at 10% or lower, by adjusting the volume of metallic silicon, silicon carbide, as well as boron carbide according to the rate of open gas pockets in the fired

[0051] Regarding this invention, when the new Highly Oxidation Resistant Silicon Impregnated Composite Material stated above is used to produce sliding members and materials to use with brakes, these sliding members and materials to be used with brakes should be produced by using a surface grinding machine to cut and process the composite material manufactured by the method stated above into suitable measurements and then finishing up the surface grinding. In the case of large scale materials of specific shapes, they can be produced by first being made into the desired mold by laminating the yarn composed from carbon fiber bundles, then by firing the desired mold, making a phase comprised from Silicon-Silicon Carbonaceous Material and boron carbide that can be included upon request on the inside and/or the surface of the yarn or the yarn sequence, and making a fired body, and impregnating and dissolving boron carbide that can be included upon request, and at the very least metallic silicon or silicon carbide, into this fired body, and forming a matrix that is made from boron carbide that can be included upon request and Silicon-Silicon Carbonaceous Material. The Highly Oxidation Resistant Silicon Impregnated Composite Material is especially suitable to be used for molding tools, sliding members, and materials for brakes that require oxidation resistance under high temperatures.

[0052]
[Working Example] Next, this invention will be explained in even more detail by using a working example, but this invention is not limited to these working examples. Further, the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention was evaluated through the method described below.

[0053] (The Oxidation Evaluation Method) A series of chambers were prepared, in which the oxygen density in the atmosphere was adjusted to 10ppm, 100ppm, 1,000ppm, 1% or 21%, and the temperature inside each chamber was set at 600 degrees Celsius. A testing example was put into chambers prepared in this manner, and that condition was kept under those conditions for 100 hours. After 100 hours had passed, each sample was taken out, had its weight measured, and the weight reduction rate (%) was calculated through the following equation.
Weight Reduction Rate (%) = [ (W1-W0)/ (W0) ] X 100
(However, in this equation, W1 displays the sample weight after being kept inside the chamber for 100 hours, W0 displays the sample weight before the test began).

[0054] (Working Example 1) While impregnating phenol resin into a carbon fiber bundle that has been pulled and arranged in one direction, 12,000 carbon fibers were bundled and combined with the metallic silicon, the phenol resin which is the precursor of the matrix carbon, and the binder, and put it in tube made with porcelain resin, which is thermoplastic resin, and the yarn which is the smallest unit in the frame structure composition was adjusted. At this time, the composition of the yarn was 40% by weight of carbon fiber, 30% by weight of phenol resin, which is the precursor to the matrix carbon, and 30% by weight of metallic silicon. A pre pregnant sheet was woven using a series of yarn that was adjusted in this manner. The necessary amount of the pre pregnant sheet series that was adjusted in this manner was laminated, and this laminated body was formed in a Hot Press that was 600 degrees Celsius and 100kg per square centimeter. A C/C Composite with a thickness of 20mm was acquired by firing this formed body in a nitrogen atmosphere with a temperature of 2,000 degrees Celsius. Using the acquired C/C Composite, the density measured with Archimedes' principal was 1.7g/cm (footnote 3) and the open gas pocket rate calculated by the same Archimedes principal was 10%.

[0055] Next, the acquired C/C Composite was set up inside the carbon pot with enough metallic Silicon powder with an average powder diameter of 1mm, and 99.8% purity, to easily reach a open gas pocket rate of 5%. Next, the carbon pot was transferred inside to the firing furnace. After the temperature inside the firing furnace was set at 1300 degrees Celsius, the quantity of Argon Gas flowing as the inactive gas at 20 NL/minute, the pressure inside the firing furnace was set at 1hPa, and the maintenance time at 4 hours, the pressure inside the firing furnace was maintained at the same level, and through raising the temperature inside the furnace to 1600 degrees Celsius, metallic silicon was impregnated in the C/C Composite and a Highly Oxidation Resistant Silicon Impregnated Composite Material with a gas pocket rate of 5% was produced.

[0056] When oxidation resistance measurement was measured using the acquired Highly Oxidation Resistant Silicon Impregnated Composite Material , as displayed in diagram 3, the weight reduction amount in the atmosphere with 1% oxygen was roughly 25%, the weight reduction amount in the atmosphere with 1000ppm of

oxygen was about 3%, and the weight reduction amount in the atmosphere with 100ppm of oxygen was extremely small; small enough to a point where it could be said the weight reduction was essentially equal to 0. When compared the C/C Composite that was tested at the same time, the reduction rate for 1000ppm was approximately less than one tenth. Even when compared to Silicon Impregnated Composite Material produced through the traditional method, when the oxygen level was less than 1%, the weight reduction rate was less than one-half, and when the oxygen level was 1000ppm, the weight reduction rate was approximately less than one third. From this fact, it is understood that the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to the intention of this invention displays an extremely high quality of oxidation resistance.

[0057] (Working Example 2) While impregnating phenol resin into a carbon fiber bundle that has been pulled and arranged in one direction, 12,000 carbon fibers were bound and combined with the metallic silicon, phenol resin which is the precursor to the matrices carbon, and the binder, and put it in a tube made with porcelain resin that is thermoplastic resin, and the yarn which is the smallest unit of the skeletal frame was adjusted. At this time, the composition of the yarn was composed 40% by weight of carbon fiber, 30% by weight of phenol resin which is the precursor body of the matrix that is 30% by weight, and 30% by weight of metallic silicon. A pre pregnant sheet was woven using a series of yarn that was adjusted in this manner. The necessary amount of pre pregnant sheet series adjusted in this manner were laminated, and this laminated body was formed in a Hot Press that was 600 degrees Celsius and 100kg per square centimeter. A C/C Composite with a thickness of 20mm was acquired by firing this formed body in a nitrogen atmosphere with a temperature of 2,000 degrees Celsius. Using the acquired C/C Composite, the density measured with Archimedes' principal was 1.7g/cm (footnote 3) and the open gas pocket rate calculated by the same Archimedes principal was 10%.

[0058] Next, the acquired C/C Composite was set up inside the carbon pot that has boron carbide and enough metallic silicon powder with a 99.8% purity level and an average diameter of 1mm to easily have a gas pocket rate of 5%. Then, the carbon pot was transferred to the inside of the furnace. After the temperature inside the furnace was 1300 degrees Celsius, the quantity of Argon Gas flowing as inactive gas was set 20 NL/minute, the pressure inside the furnace was set at 1hPa, and the maintenance time was set at 4 hours, the pressure inside the furnace was maintained at the same level, and through raising the temperature inside the furnace to 1600 degrees Celsius, metallic Silicon and boron carbide were impregnated in the C/C Composite and an Highly Oxidation Resistant Silicon Impregnated Composite Material a gas pocket rate of 5% was produced.

[0059] When oxidation resistance measurement was measured using the acquired Highly Oxidation Resistant Silicon Impregnated Composite Material , as displayed in diagram 3, the weight reduction amount in the atmosphere with 1% oxygen was roughly 2%, the weight reduction amount in the atmosphere with 1000ppm of oxygen was about 0.3%, and the weight reduction amount in the atmosphere with

100ppm of oxygen was extremely small; small enough to a point where it could be said the weight reduction was essentially equal to 0. When compared the C/C Composite that was tested at the same time, the reduction rate for 1000ppm was approximately less than one tenth. Even when compared to Silicon Impregnated Composite Material produced through the traditional method, when the oxygen level was less than 1%, the weight reduction rate was less than one-half, and when the oxygen level was 1000ppm, the weight reduction rate was approximately less than one third. From this fact, it is understood that the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to the intention of this invention displays an extremely high quality of oxidation resistance.

[0060]
[The Effect Of The Invention] The new Highly Oxidation Resistant Silicon Impregnated Composite Material of this invention is something in which the oxidation resistance is remarkably strengthened. Therefore, it can be said that it has outstanding properties as a material for as sliding materials, molding materials, and for as a material for brakes of large transport machines such as aircraft, all of which demand a high level of oxidation resistance under high temperatures. Since it has a strong resistance to high temperatures, it is also suitable to be used under high temperatures as a metal melting material

[A Simple Explanation Of The Diagram]
[Figure 1] A cross section diagram that displays a patterned diagram of the structure of the Highly Oxidation Resistant Silicon Impregnated Composite Material skeletal frame pertaining to this invention.

[Figure 2] Concerning the Composite Members formed by Silicon-Silicon Carbonaceous Material, which is one mode of the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention, diagram 2 displays a cross-section view of a cross-section structure in which one structure section is omitted, in order to explain the formation state of the Silicon-Silicon Carbonaceous Material in Composite Member.

[Figure 3] A diagram that explains the state of weight reduction when the oxidation resistance of the Highly Oxidation Resistant Silicon Impregnated Composite Material formed from the Silicon-Silicon Carbide series material, which is one mode of the Highly Oxidation Resistant Silicon Impregnated Composite Material pertaining to this invention, is tested.

[Explanation Of The Symbols]
1A, 1B, 1C, 1D, 1E, and 1F----Yarn Sequence
2A.---Yarn, 2B---Yarn, 3---Fiber Bundle (Yarn), 4—carbon silicon phase,
4A—silicon carbide phase, 5—Silicon-Silicon Carbonaceous Material,
5A—Silicon-Silicon Carbonaceous Material, 6—Yarn aggregation,
7—Highly Oxidation Resistant Si Impregnated Composite Material,
8—Matrix.

Diagram 1

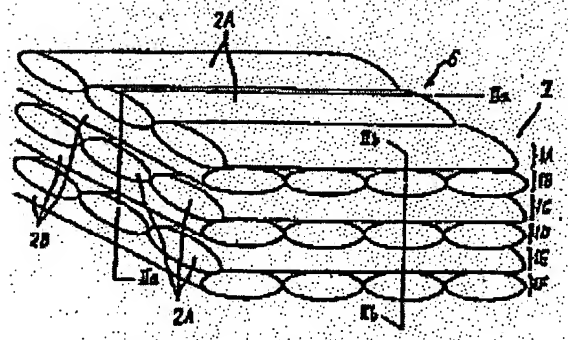
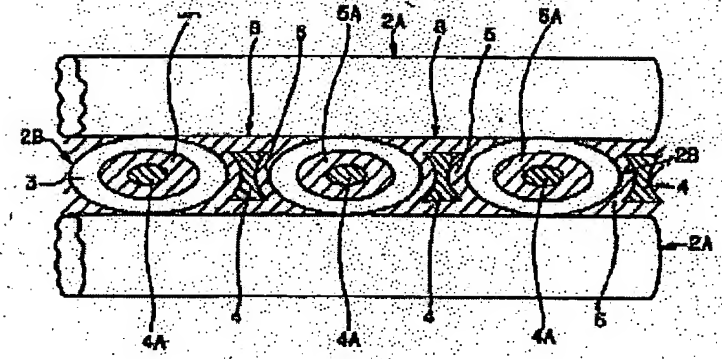
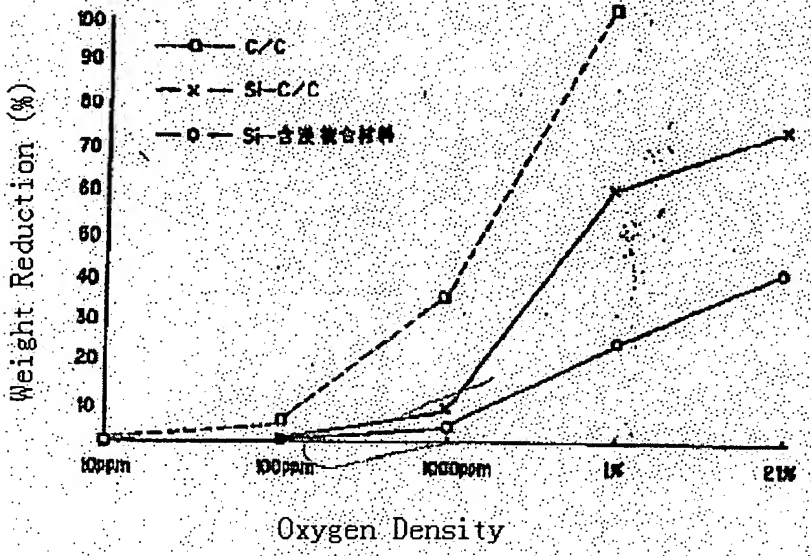



Diagram 2



[Diagram 3]


Weight Reduction (%)
100
90
80
70
60
50
40
30
20
10
C/C
Si-C/C
Si-含浸複合材料
10ppm
100ppm
1000ppm
1%
21%
Oxygen Density

Continued From The From Front Page

Term F (Reference)

3J011 LA01 QA11 SA05 SD01 SD02
SE10
4G001 BA23 BA62 BA78 BA86 BB04
BB22 BB23 BB62 BB86 BC22
BC31 BC32 BC33 BC46 BC47
BC52 BC54 BC57 BD07 BD12
BD36 BE03 BE11 BE15 BE33